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BULLETIN No. 203 AUGUST, 1912

ELM LEAF CURL AND WOOLLY APPLE APHID.

This bulletin contains a report of the migration of the woolly aphid from elm leaf curl to apple, with special reference to the economic significance of this discovery for nursery stock and young orchards. A general account of this serious and wide spread apple pest is included.

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BULLETIN No. 203.

ELM LEAF CURL AND WOOLLY APPLE APHID.*

EDITH M. PATCH.

The dual personality of certain aphid species is a condition which, before it is detected, betrays the economic entomologist into many futile combative attempts; but on the other hand the same duality may reveal, when once discovered, the most vulnerable point of attack. It is not necessary to go out of our own state for illustrations. The discovery that *Chermes abieticolens* Thomas 1879 which makes cone-like galls on black and red spruce is the same species as *Chermes pinifoliae* Fitch 1858,** which lays eggs on new growth white pine for progeny that render the pine shoots weakened and unthrifty, gives the landscape gardener his clue. If he treasures the beauty of a group of white pines he would do well to exclude red and black spruces from the vicinity, or conversely if he wishes to grow black spruces with normal branches it is an indiscretion to place them near white pines. Again, when once it was ascertained that the common Alder Blight, *Pemphigus tessellata* Fitch 1851, was masquerading on the maple (*Acer saccharium* L.—*dasycarpum* Ehrh. and cultivated varieties) as *Pemphigus acerifolii* Riley 1879,† the owner of ornamental cut leaved maples had a theretofore unsuspected means of protecting their foliage by the control of the pest on its alternate food plant, the alder, which in many circumstances is an easy point of control.

The economic application of the case in hand is apparently as direct and simple as the two just cited and since we are here concerned with one of the most serious of the apple tree pests,

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* Papers from the Maine Agricultural Experiment Station: Entomology No. 58.

** Bulletin 173 Maine Agricultural Experiment Station.

† Entomological News, 1908, p. 484; Journal of Economic Entomology 1909, Vol. II, p. 35; Bulletin No. 195 Me. Agr. Exp. Sta., Feb. 13, 1912.

the significance of the recent discovery * that the elm leaf curl harbors the "wolf in sheep's clothing" is an important factor to be taken into consideration in dealing with the woolly aphid of the apple.

While working over some elm aphides several winters ago I found that I was unable to separate on structural characters certain collections of *Schizoneura americana* (causing and inhabiting elm leaf curl) from certain collections of *Schizoneura lanigera* (the troublesome woolly aphid of the apple). Collections could be selected which showed apparently significant antennal differences but others could be selected which could only be separated by reference to the tree from which they had been taken. Notice in this connection antennal figures 449 to 459. (As a study of the antennal variation in 1,000 individuals of this species is nearly ready for press, further discussion of this point is not necessary here.)

This circumstance brought no real conviction, for *lanigera* (described in 1802) has been under economic surveillance for more than 100 years and Riley (1879) gives descriptions of seven consecutive generations of *americana,* from the stem mother to the true sexes inclusive, all on the elm. On the other hand spring and return migrants of *americana* had been recorded from the widely separated localities of Idaho (Aldrich 1901), Kansas (Sanborn 1904) and Maine (Patch 1910) and their summer residence was still a mystery. Moreover the overwintering of *lanigera* on the apple roots was, though confusing, no argument against another host for the winter egg, for, as was shown for the Alder Blight, the all year presence of apterous forms on the alder was coincident with a migration to the maple for the deposition of the true sexes and the winter eggs. (Bulletin No. 195 of this Station).

Field observations were made during two seasons with this problem in mind but brought no solution, the summer occurence of *rileyi* which I consider to be an elm bark form of *americana* (See Me. Sta. Bul. 181, p. 237) complicated the situation, while the fact that both hosts were under out door conditions, not easy of control, left too much room for doubt.

This past winter, however, material under control conditions was secured by raising seedling apples in the greenhouse where

* Science, Vol. 36, p. 30. "Elm Leaf Curl and Woolly Aphid of the Apple."

infestation from the woolly aphid was rendered impossible. Leaf curl from elm with pupae and alate forms were secured from the south some time before material at the same stage would be available here, and migration tests were made. The winged forms from the elm were caged over seedling apples, and their progeny, growing along creases where the thin bark is scaling back, in the axils of the leaves and on exposed roots of the apple seedlings, covered by typical flocculent white secretion, are unmistakably the woolly aphid of the apple. (Fig. 448). The colony in the figure just cited was started May 12-13, by migrants from elm leaf curl. Their progeny thrived from the first and the photograph was taken May 29, the day on which the first apterous generation on the apple began to give birth to young.

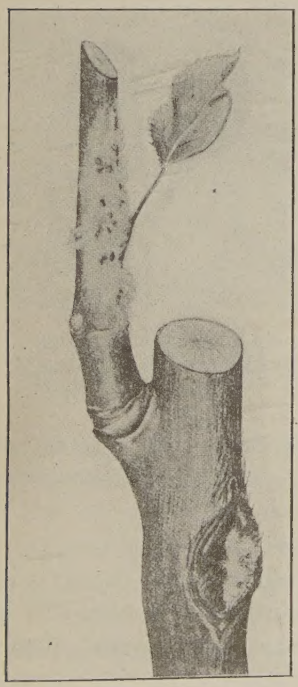

Fig. 438. Bark colonies of Woolly Aphid on apple. (From Alwood.)

On part of the seedlings similar tests were unsuccessful, the nymphs dying very soon or in one case after about two weeks tardy growth. This was probably due to aphid resistant seedlings, the apples from which the seeds were planted being from several different varieties, and as is well known all apples are not alike susceptible to attacks from the woolly aphid.

Habits.

The woolly aphid occurs upon the apple as a bark feeder and is found upon branches, roots, and tender places on the trunk. These insects are covered by a white flocculent waxy secretion given off as fine filaments through pores in the skin and their colonies are thus readily detected by the masses of white "wool" which renders them conspicuous. (Figs. 438 and 448.)

On the roots its attacks induce enlargements or galls or swellings, and in the creases of these

malformations the root form occurs in clustered masses. The injury to the trees is due both to the sucking up and exhaustion of the vital plant juices and to the poisoning of the parts attacked, as indicated by the consequent abnormal growths. Fig. 439.

The damage is particularly serious in the case of nursery stock and young trees and is less often important after the tree has once become well established and of some size. Where this insect is abundant all the roots of a young tree to the depth of a foot or so become clubbed and knotted by the gowth of hard fibrous enlargements with the results in a year or two of the dying of the rootlets and their ultimate decomposition with attendant disappearance of the galls and also of the lice, so that after this stage is reached the cause of the injury is often obscure.

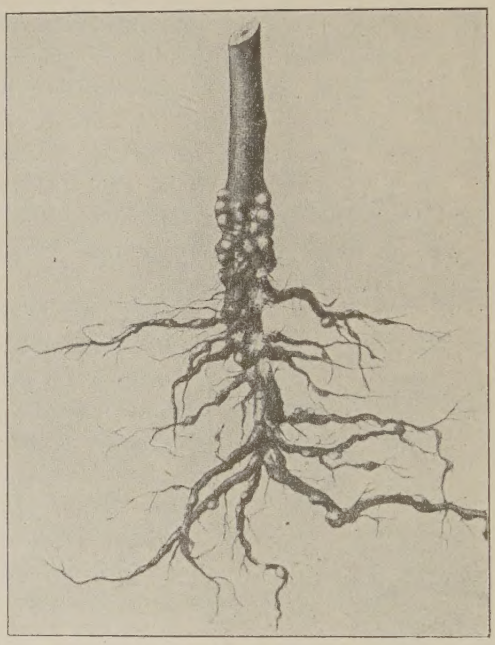

Fig. 439. Crown and root of young apple tree, showing characteristic swellings or galls produced by the root lice. (From Alwood.)

On the trunks the presence of the lice results in the roughening of the bark or a granulated condition which is particularly noticeable about the collar and at the forks of branches or on the fresh growth around the scars caused by pruning, which latter is a favorite location. On the water shoots, they collect particularly in the axils of the leaves, often eventually causing them to fall, and on the tender growth of the stems. The damage above ground, though commonly insignificant, is useful

as an indication of the probable existence of the lice on the roots. A badly attacked tree assumes a sickly appearance and does not make satisfactory growth, and the leaves become dull and yellowish, and even if not killed outright it is so weakened that it becomes especially subject to the attacks of borers and other insect enemies.

The common forms both on the roots and above ground are wingless lice, not exceeding one-tenth of an inch in length, of a reddish-brown color, and abundantly covered, especially in those above ground, with a flocculent waxy secretion. (Fig. 441.)

In autumn, among the wingless ones, winged females, Fig. 440, appear in abundance. They are little, clear-winged, gnat-

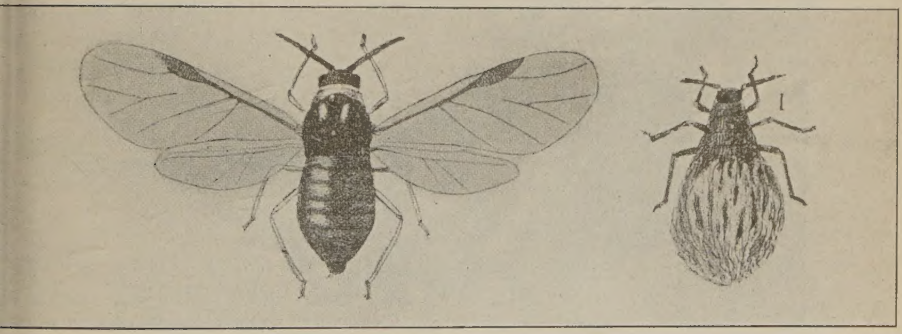

Fig. 440. Fig. 441.
Woolly Aphid. Winged and wingless forms. Greatly enlarged.
(From Marlatt.)

like objects, greenish-brown, almost black in color, with the body covered with more or less of the cottony secretion. These are the fall or return migrants that seek the elm bark to give birth to the generation of true sexes,—minute wingless, beakless creatures, the female of which deposits a single "winter egg" within a crevice of the elm bark.

On the elm the stem mother, which hatches from the overwintering eggs sheltered in rough crevices of the bark, appears early in the spring and may be found in Maine before the middle of May stationed on the partly opened leaf buds.

By the last of May the earliest of these wingless stem mothers (Fig. 443) are mature and found in the leaf curl (Fig. 442) or

rosette (Fig. 462, when a group of terminal leaves are affected) which they cause, producing the next generation, which are also wingless.

In the summer great numbers of winged individuals are developed. From the fact that Riley recorded 7 consecutive generations on elm and the occurence of what seems to be the elm bark feeding generations of the same species (known as *rileyi*) during the summer on tender elm bark, it would seem either that the migration from the elm leaves of these summer migrants

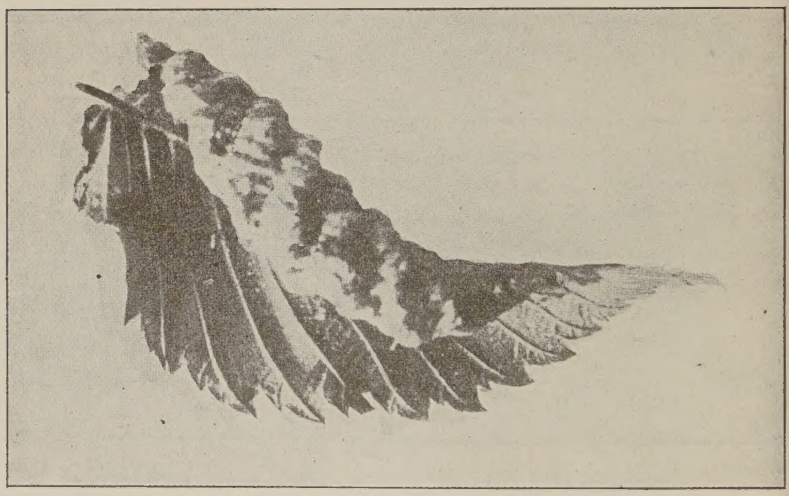

Fig. 442. Elm leaf curl, in which the alate spring migrants develop before taking flight to apple bark.

is partly to apple bark and partly to elm bark or that elm bark colonies as well as leaf curl may be established by the first or second apterous generations. Such a life cycle is indicated in the accompanying table. This does not account for the generations resulting from the overwintering forms on the apple roots as their sequence yet remains to be studied. The fall migration of the woolly aphid from apple and the mountain ash I have observed but I have not yet from observation linked it with the true sexes on elm. That inference, however, from the evidence of the spring migration to apple is unmistakable.

There are still several important details to be worked out for the woolly aphid of the apple and elm. Whether the elm bark

colonies are originated by the stem mother, or by migrants from the leaf curl or both; whether the mid June (in Maine) winged forms from the elm bark colonies migrate to apple or scatter to other elm bark, or both; the significance of the difference in antennal types of migrants from elm leaf curl (Figs. 451, 452, 454, and 458), whether indicating locality or conditional variation; and complete sequence upon each food plant;—are subjects for further study.

These points can for the most part be watched only with colonies upon seedling stock of the food plants in confinement under such conditions that perfect control of the material can be secured. While I have further work along these lines already under way, some of the problems will need extended observations and it has seemed desirable not to wait until all tangles are straightened out before publishing the main fact of the migration test from elm leaf curl to apple bark as this point has an important bearing for young trees in nurseries and new orchards and the economic significance of the migration data will not, so far as can be anticipated, be influenced by further detailed study of the different generations.

The Spring Migration.

The fact of the migration from elm leaf to apple and mountain ash under normal out of door conditions was established during the summer of 1912. The migrants from the elm leaves settle on the under side of the apple leaves of water shoots and there produce nymphs which seek the stem at leaf axils and there congregate in woolly masses. The mountain ashes (*Pyrus americana* and introduced species) are favorite summer hosts in Maine. From one native mountain ash at Orono more than 400 such migrants were removed July 2 to July 12 from the ventral surface of the leaves, and about 150 thriving clusters of woolly aphid nymphs, the immediate progeny of these migrants, were established on the shoots of this single tree.*

In this connection it may be of interest to record a forced migration test. On June 21, 1912, I placed several hundred elm

*A more detailed account of this occurrence is to be published in the October issue of the Journal of Economic Entomology.

leaf migrants at the base of water shoots of an uninfested mountain ash on the Campus. As the migrants are much more docile about sundown than earlier in the day this was done about 7 P. M. They moved but little, most of them creeping to the ventral side of a leaf and remaining there; and during the night producing nymphs which sought the leaf axils of the water shoots so that by the afternoon of June 22, the tiny nymphs had already fed enough and secreted enough white wax to give the typical "woolly" appearance to the young colonies. These and the progeny thrived on the mountain ash in a perfectly normal way.

SEQUENCE OF GENERATIONS. DESCRIPTIVE.

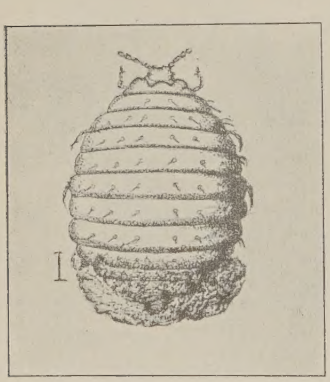

Fig. 443. Stem mother. (From Riley.)

Egg 0.5 mm. long, gamboge-yellow, inclining to brown in color, with no especial external sculpture. In crevices under elm bark.

Stem mother: Pale yellowish-red, with black members when first hatched; the red deepening and becoming purplish or livid with age. When mature, averaging 3.5 mm. in length, globose or pyriform, with subobsolete honey-tubes and six dorsal rows of darker piliferous and tuberculous spots. Antenna 5-jointed, joint 3 more than equaling 4 and 5 together in length. Causing and inhabiting elm leaf curl.

Second generation. Apterous viviparous forms which do not become so large as the stem mother. The antenna is normally 6-jointed (Fig. 461). Inhabiting leaf curl and giving birth to migrants.

Third generation. Winged viviparous female: Body dusky, the abdomen slightly reddish; legs either dusky or yellowish red. Antennæ as long as head and thorax together, dusky, rarely yellowish, not pilose, but with a few short setous points; 6-jointed. The annulation of the joints in different collections and from different localities varies greatly. Figs 451, 452, 454.

and 458, cover the ordinary range. The absolute size of this generation is subject to considerable variation. These develop within and migrate from the elm leaf curl, and settling on apple produce young which inhabit apple.

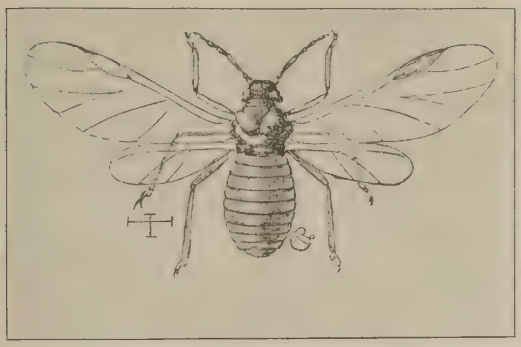

Fig. 444. Third generation. (From Riley.)

Fourth generation. That from the first winged females: Differs from the preceding in the promuscis being much longer. The antennæ have 6 joints, with no annulated constrictions. The color is sometimes decidedly orange. When newly hatched, the thickened end of the promuscis often extends one-half the length of the body beyond caudal extremity. It is born with an enveloping pellicle or pseudovum, and though of a bright red with pale legs at first soon becomes brownish, with dark members. Deposited on apple by the spring migrants and developing there in flocculent masses. Fig. 448. When mature, if the colony is crowded, some of the individuals move to a new cite on the apple bark before giving birth to the nymphs which settle near and establish thus new colonies. In other cases the nymphs themselves scatter to new cites.

Fifth generation. The second apterous generation on apple bark. Practically like the fourth generation.

Sixth? generation. From about the first of September until frost the winged fall migrants develop in the woolly colonies on apple, mountain ash, and *Crataegus* whence they migrate to elm bark to deposit their progeny, the true sexes. Figs. 455, 456, 457 and 459 give the antennæ of the fall migrant.

Together with these in the same woolly colonies develop apterous viviparous females that give birth to nymphs which seek the roots of the trees and hibernate there, surviving the winter if the conditions are favorable.

True sexual individuals: Born within an egg-like pellicle; the antennæ 5-jointed, with the joints subequal. Orange in color. Undergoing one molt, and then being at once distinguished from the other forms by the brighter orange-yellow color, the rudimentary mouth, the more simple eyes (composed of three facets), by the shorter, 5-jointed antennæ, the joints subequal in length, by the shorter legs, with smaller claws to the tarsi, and more distinct terminal capitate hairs or pulvilli. The skin is transparent, the body filled more or less with fatty globules. The female is nearly pyriform, and averages 0.4 mm. in length. A single egg is visible through the translucent skin and occupies nearly the whole of the body. The male is narrower and smaller. Figs. 446 and 447.

This generation seems to have no object in life except the deposition of eggs, since they can not eat or fly. The eggs are placed in the deepest crevices of the bark, especially those that are tangential to the tree, and are not easy to find. The small lice perish after depositing eggs leaving only the latter to survive the winter.

Economic Status.*

The danger from the woolly aphid is greatest to nursery stock and young orchards. Mr. Marlatt (Journal of Economic Entomology, Vol. 4. pp. 116-117) in recording the use of American-grown apple seedlings says:—"Mr. F. W. Watson, of Topeka,

* "Mr. W. S. Griesa, proprietor of Mt. Hope Nurseries, Lawrence, Kan., has established the Griesa Research Fellowship in Entomology in memory of his father, the late A. C. Griesa. In establishing this fellowship it was the wish of the founder that the holder should devote himself to a fundamental investigation of one of the several entomological problems ever present with nurserymen.

"Upon consultation, it was decided to select for the theme of this research the Woolly Aphis. Mr. H. W. Lohrenz, A. B., McPherson College, and a graduate student at the University of Kansas, was elected by the regents of the university to this fellowship.

"The purpose of this research is, after careful experimentation in remedy and prevention, and investigation into the life cycle of this Aphis, to devise a practical means whereby nurserymen can properly deal with this economic problem in such a way as to eliminate the losses now attending the existence of this insect on nursery stock.

* * * * * * * * * * *

"It is worthy of note as showing the interest of nurserymen generally in foundations of this nature that the Western Nurserymen's Association, an organization of nurserymen of the Middle Western States, passed resolutions commending the founder of this fellowship for the work he has instituted." Journal of Economic Entomology. Vol. 4, p. 161.

Kans., in an article in the *National Nurseryman* for January, 1910, p. 437, on "American-grown Apple Seedlings," states that from twenty to forty million of American-grown apple seedlings are used in this country every year, the production of about a dozen nursery firms. The bulk of the seed used comes from France, and therefore is of the same stock as the imported French seedlings."

Mr. Lohrenz (1911) in recording observations on two-year-old nursery stock made at three nurseries containing respectively about 30,000; 45,000; and 300,000 trees, states that he found from 20 per cent to 25 per cent of the trees infested by the woolly aphid.

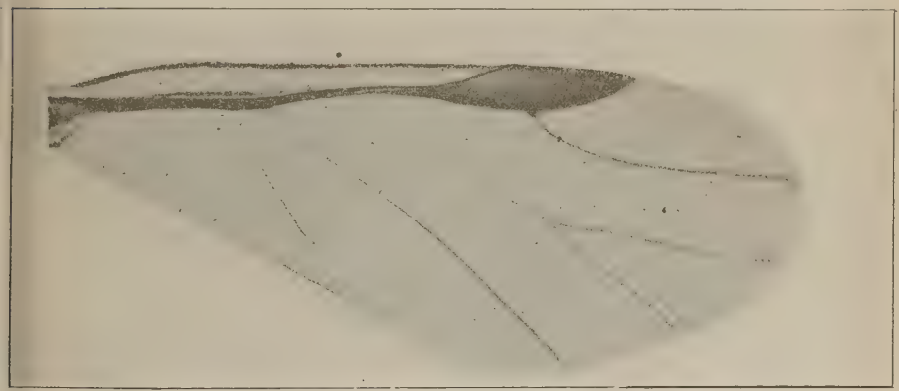

Fig. 445. Fore wing of migrant from elm leaf curl to apple. Third Generation.

In circular No. 20, Bureau of Entomology, U. S. Department of Agriculture (revised edition 1908) the woolly aphid of the apple is characterized as "one of the worst enemies of the apple."

Mr. Alwood (1904) of the Virginia State Crop Pest Commission in his excellent account of this insect states "On nursery stock the woolly aphis is a most serious pest, and under some circumstances it ruins a large percentage of the apple trees in the nursery."

On page 5 of Bulletin 133 of the Colorado Experiment Station the following statement is made:

"If Colorado orchardists should vote their opinion as to what ought to be called the worst orchard pest in the state, it is very

doubtful whether the codling moth, or the woolly aphis, would carry off the honors."

Although it would be easy to compile testimony of this character against the woolly aphid as an enemy to young apple trees from numerous and widely separated parts of our country, they would be chiefly a repetition of what has already been said.

That the elm leaf curl renders the foliage of this stately tree unsightly during years of heavy infestations is well enough known in all parts of the country where the American elm is grown. Professor Gillette (Journ. Ec. Ent. Vol. 2, p. 356)

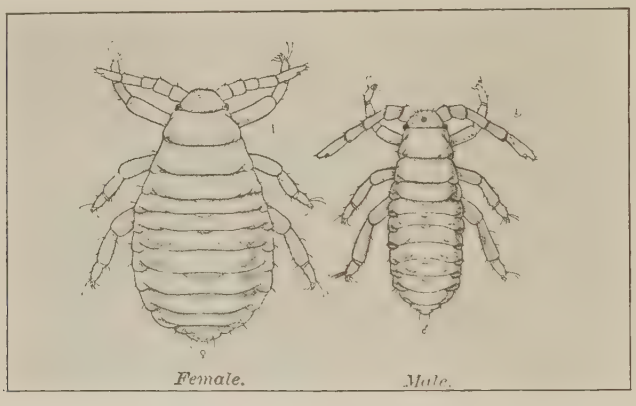

Fig. 446 and Fig. 447. Mature sexual individuals of the Woolly Aphid,—the oviparous female and male. (From Alwood.

states of this insect,—"This louse is a real pest upon white elm nearly everywhere that this tree is grown in Colorado."

In Montana where the white elm (*Ulmus americana*) is being established as a shade tree the insects of the elm leaf curl have taken up their abode but have found no cordial welcome for Professor Cooley says of them (Cooley 1904, p. 44).

"Altogether they are a decidedly obnoxious pest. Not only do they distinctly injure the trees but they disfigure them as well and furnish an attraction for ants, flies and other insects which visit them for the sweet liquid."

LIFE CYCLE OF WOOLLY APHID OF APPLE.

ELM: Primary Host.	APPLE: Alternate Host.
EGGS. (Under bark all winter)	NYMPHS. (From hibernating forms on roots, etc.) migrating to trunk or branches in early spring.
STEM-MOTHER. (first generation in leaf curl. Apterous viviparous females).	
SECOND GENERATION. (apterous viviparous females in leaf curl).	SEVERAL GENERATIONS.
SPRING MIGRANTS (third generation. Alate viviparous).	Migrate to apple . . . . >
	FOURTH GENERATION. (apterous viviparous females).
SUMMER GENERATIONS. ON ELM BARK.	
	FIFTH GENERATION. (apterous viviparous females).
Migrate to elm < . . .	FALL MIGRANTS. Alate viviparous parthenogenetic females, mature Sept.-Oct. sexuparae.
	APTEROUS VIVIPAROUS PARTHENOGENETIC FEMALES, mature in Sept.-Oct.
APTEROUS OVIPAROUS FEMALES AND APTEROUS MALES.	
EGGS. (under bark all winter).	HIBERNATING FORMS ON APPLE ROOT.

Preventive and Remedial Measures.

The foregoing account of the habits and characteristics of the woolly aphid will suggest certain measures to control it.

The protection of seedling apples from infestation by the woolly aphid while still in the nursery has heretofore been an exceedingly difficult matter it would seem from the amount of infested stuff that is yearly condemned. But with the knowledge that the source of danger lies in the migrants from the previously unsuspected elm curl, it is seen to be possible to control the nursery stock by establishing nurseries at a safe distance from susceptible elm trees or clearing out the elms from the vicinity of large nurseries. As there are many places in the country where the elm is not at all abundant this would often be entirely practicable and where so would be the simplest and most effective method of protection. As it is the seedling trees that are most susceptible to injury and when attacked most seriously damaged by the woolly aphid a method of protection for the young trees while in the nursery is the most desirable.

The raising of the elms and apples in the same nursery is thus seen to be a hazardous proceeding and should be avoided.

Again young orchards of clean stock set in parts of the country where the elm is not grown should be successfully protected by excluding elms from the choice of shade trees. Indeed, the matter of alternate hosts of the aphid enemies concerned should always be borne in mind in planning the trees for an estate, and only one of the two hosts necessary for the life cycle of a migratory aphid planted, where the pest is a serious one.

It is desirable that data concerning the relative susceptibility of different varieties of apple should be accumulated with a view to using the more resistant for root stock, if otherwise practicable.

In dealing with infested apple trees the aphid masses on trunk and branch present no especial difficulty, and can be very readily exterminated by the use of any of the washes recommended for plant-lice, such as tobacco decoction, kerosene emulsion, a strong soap wash (Formulas a, b, c, d), the only care necessary being to see that the wash is put on with sufficient force and thoroughness to penetrate the covering and protecting cottony secretion. If the wash be applied warm, its penetration will be considerably increased.

The much more important root feeders, however, are more difficult to reach and exterminate. The common recommendations are of applications of strong soap or tobacco washes to the soil about the crown, or soot, ashes, or tobacco dust buried about the roots; also similarly employed are lime and gas-lime.

Badly infested nursery stock should be destroyed, since it would be worth little even with the aphides removed.

Proper cultural methods can hardly be overestimated in their value as a protection of young trees, as neglected orchards not only suffer heavily but serve as a breeding ground, dangerous to the neighboring trees.

FORMULA A—TOBACCO DECOCTION.

Tobacco stems or tobacco dust.....	2 pounds
Water	4 gallons

Put the tobacco in the water, enough to cover, which may be either cold or hot. Place over the fire and when the water has reached the boiling point, remove some of the fire and allow the water to simply *simmer* for fully one hour, when the liquid is ready to be drained off, diluted to the above proportions and applied. Boiling violently drives off the nicotine.

If whole-leaf tobacco is used, prepare as above, using one pound of tobacco to each four gallons of water.

No lime or other alkaline substance should be added to the tobacco *while cooking.* Apply at once, or within a few days after making if possible.

Certain reliable extracts such as *"Black Leaf," "Black Leaf 40,"* and *"Nikoteen"* are on the market and can be secured through local druggists. (The Black Leaf preparations are manufactured by *The Kentucky Tobacco Product Company,* Louisville, Ky., and are carried by the Collins Hardware Company, 97 Friend St., Boston, Mass. *Nikoteen* is manufactured by The Nicotine Manufacturing Company, St. Louis, Mo., and can be secured from Joseph Brick & Sons, 47-54 N. Market St., Boston, Mass.).

Directions for use come with the products. There is nothing to do in the preparation of these extracts except to stir the contents of the can before pouring out any quantity for dilution. In most cases one gallon of the *Black Leaf* will be found sufficient for each seventy gallons of water. But if in the treatment of any louse this does not seem sufficient it may be used in preparation of one gallon to sixty or sixty-five gallons of water. Careful sprayers have usually succeeded in killing plant lice with this preparation in the proportion of one gallon to each one hundred gallons of water. Thoroughness of application is of as much importance as the strength of the material used.

Nikoteen is a more concentrated abstract, 1 part being used with from 400 to 600 parts of water.

Black Leaf 40 is a concentrated solution of nicotine-sulphate and is widely and successfully used in large western orchards, at the rate of 1 part to 700 or 900 parts of water.

It is the common practice to add soap,—whale oil soap or good laundry soap at the rate of 2 bars to 50 gallons. This is to lessen the formation of drops, causing the spray to cover surfaces more in the form of thin film.

Better success is obtained by some by using a little lime instead of soap, the inert solid in suspension aiding the extract to "wet" and "stick" to the bodies of the aphides. For this purpose 1 pound of stone lime, slaked and strained into 50 gallons of tobacco extract as prepared for application, is sufficient.

Formula B.—Kerosene Emulsion.

Hard Soap	1-2 pound
Boiling Water	1 gallon
Kerosene	2 gallons

To prepare, dissolve one-half pound of soap in one gallon of soft water by boiling; when well dissolved and still boiling hot, remove from the fire and add two gallons of kerosene, and agitate at once as briskly as possible. The emulsion is more readily made if the kerosene first be heated by immersing the vessel containing it in a larger vessel of boiling water. *Never* heat the kerosene over a direct fire.

If large quantities are being made, a good way to emulsify is to use a force pump and spraying nozzle and pump the mixture as forcefully as possible back into the vessel containing it. If the emulsion is properly formed, the whole mass will appear much like whipped cream and will mix readily in water without a film of oil rising to the top.

As soon as emulsified, add twenty-seven gallons of water and use at once. This will make thirty gallons of the mixture, and such an emulsion will be one-fifteenth oil (or a 7 per cent emulsion). This is the strength ordinarily used for the destruction of insects upon plants. For larger or smaller quantities, prepare in the same proportions.

Sometimes the emulsion is not perfect and a little oil rises to the top. In such cases, if the last in the barrel or tank is pumped out upon the foliage, it is likely to burn it. So it is advisable, unless the emulsion is of good quality, to throw out the last few gallons, making no use of it.

It is best to dilute and apply kerosene emulsion as soon as it is prepared.

Avoid using alkali or any hard water in making the emulsion, as it will cause the oil to separate and rise to the top. Any clean, soft water will usually give good results.

Formula C.—Miscible Oils.

There are several miscible oils upon the market which may be added directly to water forming a milky emulsion at once. In the preparation of any of these, such as "Scalecide," or "Target Brand Scale Destroyer"

or "Killoscale," add the oil directly to the water with a little stirring. One gallon of the miscible oil in 30 to 50 gallons of water will make a mixture, which in most cases will be strong enough to kill plant lice, if thoroughly applied.

Formula D.—Whale-oil or Fish-oil Soaps.

The so-called whale-oil or fish-oil soaps which are quite extensively used for the destruction of plant lice, will usually be effective if thoroughly applied in the proportion of one pound of the soap to each six or eight gallons of water. There are numerous brands of these soaps upon the market. Among those that have been used quite successfully are Good's Whale-Oil Soap and Bowker's Tree Soap.

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In recent years tobacco extracts have rapidly taken the place of other remedies for aphides, and well informed apple growers are using them almost to the exclusion of other insecticides. It should be remembered that this is a contact insecticide and kills only the insects actually touched. It is, therefore, necessary to be very thorough in the spraying.

Insect Enemies of the Woolly Aphid.

So far as the natural enemies of this pest are concerned its residence in the elm leaf curl is a vulnerable period strongly subject to attack. Very abundant in Maine working on the aphides while in the elm leaf curl are a predaceous capsid, (*Camptobrochis nitens*), flocculent larvæ of a Coccinellid and syrphus maggots. So numerous are all these insects in certain years that it has sometimes been difficult for me to secure enough of this aphid for experimental purposes,—a search through many emptied leaf curls being necessary before aphides could be found.

In other parts of the country also this aphid is preyed upon while in the elm leaf curl and frequently the only living arrivals in material sent me from other states has been the predaceous insects within the leaf curl.

Riley (1879) records as follows:—"Among the more prominent of the natural enemies of this species I have noticed, of Coleoptera, *Coccinella 9-notata*, *Coccinella sanguinea* (*munda*) Say, *Hippodamia convergens*, and several species of *Scymnus*. I also found feeding upon them the perfect beetle of *Podabrus modestus*, and the Hemipterous *Cyllocoris scutellatus* Uhler, and *Capsus linearis* Beauv. A Lepidopterous inquiline, namely, the larva of *Semasia prunivora* Walsh is also quite common within the curled leaves, feeding both on the lice and on the substance of the leaf. A large green *Syrphus* larva and several *Chrysopa* larvæ also prey upon them."

While on the apples the woolly aphid is subject to the attacks of a number of insect enemies, those recorded by Marlatt (1897) including "the parasitic chalcis fly, *Aphelinus mali* Haldemann, and the larva of a syrphus fly, *Pipiza radicum* Walsh and Riley, and also the larva and adult of several species of lady birds, the larvæ of lace-wing flies, and spiders, etc. In the East a very small brown species of ladybird, *Scymnus cervicalis* Muls., is often present in some numbers, and the common nine-spotted ladybird, *Coccinella 9-notata* Hbst., is also an active enemy of the woolly aphid.

"The most active natural enemies of the woolly aphis in Colorado have been predaceous insects. We have reared no parasite from it, but, Aug. 21, 1908, Mr. L. C. Bragg brought into my office a female *Aphelinus mali* busily ovipositing in apterous females of this louse. Among the Coccinellids, *Hippodamia convergens* is by far the most abundant destroyer of this louse both upon the eastern and western slopes of the mountains. Mr. E. P. Taylor also took *H. sinuata, Coccinella 9-notata, C. monticola* and *C. transversalis* feeding on this louse in the orchards about Grand Junction, and we have noted *H. transveralis, C 9-notata, C. monticola, C frigida,* and *C. 5-notata* (*transversalis* and *transversoguttata*) feeding upon it in eastern Colorado.

"Mr. Taylor also reared two syrphus flies at Grand Junction on this louse, namely, *Catabomba pyrastri* Linn, and *Eupcodes volucris* O. S.

"Lace-wing flies are also very destructive to *Schizoneura lanigera* in Colorado, and especially upon the western slope in the Grand Valley, where Mr. Taylor concluded that they did more than all else to subdue the unusually severe outbreak of this louse in that valley during the early summer of 1907. The Capsid, *Camptobrochus nebulosus* Uhl, we have found a common feeder upon this and some other plant lice in Colorado." (Gillette 1908).

Food Plants.

Crataegus Crus-galli (lucida). *Schizoneura crataegi* Oestlund. Davis, 1910, p. 412.

Crataegus punctata Jacq. *Schizoneura crataegi* Oestlund. Oestlund, 1887, p. 28. (Now considered *lanigera* by Professor Oestlund).

Crataegus tomentosus L. *Schizoneura crataegi* Oestlund. Williams, 1910, p. 20.

Crataegus sp. *Schizoneura lanigera.* Patch, 1912a, p. 236.

Pyrus malus L. *Schizoneura lanigera* Hausmann. Alwood, 1904. Gillette and Taylor, 1908, p. 28.

Pyrus sitchensis. *Schizoneura lanigera.* Patch, 1912a, p. 236. (Also on two other cultivated species of mountain ash).

Ulmus americana L. *Schizoneura americana.* Riley and *Schizoneura rileyi* Thomas (*Eriosoma ulmi* Riley). Patch, 1910a. Williams, 1910.

Ulmus campestris L. *Schizoneura ulmi* L. (*americana* Riley). Gillette, 1909, p. 356.

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Ulmus campestris L. *Schizoneura ulmi* (Linn). (*A. foliorum* De Geer) (*S. americana* Riley?) Buckton, Vol. 3, pp. 98, 100.

Ulmus sp. *Schizoneura ulmi* Linn (*fodiens* Buckton) Tullgren, 1909. p. 169.

Ribes sp. *Schizoneura ulmi* Linn. (*fodiens* Buckton) Tullgren, 1909, p. 169.

Synonymy and Literature.

A complete bibliography for this species is not desirable here as the accounts which throw original light upon the life history would be lost in a mass of publications compiled for economic purposes.

1802. *Aphis lanigera,* Hausmann, Beiträge zu den materialien für eine kunftige Bearbeitung der Blattlause. Illigers Magazine. T. I.
Coccus mali. Bingley (Thomas 1879, p. 126).
Eriosoma mali. (Leach MSS.) Samouelle. (Thomas, 1879, p. 126).
Myzoxylus mali. Blot. (Thomas, 1879, p. 126).

1841. *Eriosoma* (*Aphis*) *lanigera,* Harris. Report on the Insects of of Mass. injurious to vegetation, p. 193.

1841. *Schizoneura lanigera,* Hartig, Germar's Zeit. Ent. III, p. 359.

1851. *Eriosoma pyri,* Fitch. Fourth Report of the N. Y. State Cabinet of Nat. Hist., A. D. 1851, p. 68.

1856. *Pemphigus pyri.* Fitch. First Report on the Noxious, Beneficial and other Insects of the State of New York, p. 5. An account of the work upon the roots and a description of the young nymph and winged individuals, the latter evidently either with abnormal venation or an accidental migrant of a different species as this form is described with the venation of a *Pemphigus.*

1858. *Pemphigus americanus?* Walker. List of the specimens of Homopterous Insects in the collection of the British Museum.

1862. *Eriosoma* (*Aphis*) *lanigera,* Harris. Insects Injurious to Vegetation, p. 242.

1869. *Eriosoma* (*Pemphigus*) *pyri,* Riley. Insects of Missouri I, p. 118. Economic account of work on apple roots.

1869. *Eriosoma ulmi,* Riley. Insects of Missouri I, p. 123. Description of winged forms and nymphs, and account of work on elm bark.

1879. *Schizoneura americana,* Riley. Bul. U. S. Geol. and Geograph. Survey, Vol. V, No. 1, pp. 4-9 and Plate I and Fig. 2. Description of seven generations on elm, with an account of the work on elm.

1879. *Schizoneura americana,* Thomas, (III), Report of the State Entomologist Ill. VIII, p. 202. Quotes Riley's description of seven generations, and concludes (p. 204): "This as admitted by Professor Riley is very closely allied to *Schizoneura ulmi,* Linn, and it is doubtful whether it should be considered as distinct."

1876-1879. *Schizoneura rileyi,* Thomas. Trans. Ill. Hort. Soc., 1876, p. 191; id. Rept. Ent. Ill. 8: 136, 137, 1879, nom. nov. for *Eriosoma ulmi* Riley. Systematic discussion and description of work. Description of insect quoted from Riley.

1879. *Schizoneura lanigera,* Thomas, III. Report of the State Entomologist Ill. VIII, p. 126. Important historical discussion.
1879. *Schizoneura ulmi,* Linn., Thomas (III) Rept. of the State. Ent. Ill., VIII, p. 140.
1885. *Schizoneura rileyi,* Forbes. Rept. Ent. Ill. 14: 114.
1887. *Schizoneura americana,* Oestlund, O. W. Aphid. Minn. p. 27. Description of winged form and pseudo gall.
1887. *Schizoneura crataegi,* Oestlund. Aphid. Minn. p. 27. Description of winged form and account of attack on *Crataegus punctata.* (Now considered to be the same as *lanigera* by Professor Oestlund.)
1888. *Schizoneura rileyi,* Lintner. 3rd Report, p. 125.
1890. *Schizoneura rileyi,* Packard. Fifth Rept. U. S. Entom. Com. Wash. Original description of insect quoted.
1890. *Schizoneura americana,* Packard. Fifth Rept. U. S. Entom. Com. p. 279. Extract from Riley Bul. U. S. Geol. and Geograph. Survey, Vol. V, No. 1.
1897. *Schizoneura americana,* Gillette, C. P. Bul. Div. Ent. U. S. Dept. Agric. 9 (n. s.): 78-79. Description of work.
1897. *Schizoneura lanigera,* Marlatt, C. L. Circ. 20, Second Ser., Div. of Ent.
1898. *Schizoneura americana,* Gillette, C. P. Bul. A. E. S. Colo. 47: 35-36. Account of work. Economic treatment. Fig. 32 photo of work.
1899. (1900). *Schizoneura americana,* Harvey. Bul. Me. Agr. Exp. Sta. No. 61. *Indem.* Ann. Rept. of Me. Agr. Exp. Sta. for 1900, p. 32. Mentioned as abundant. Photograph of leaf curl.
1900. *Schizoneura americana,* Lugger. Bul. No. 69. Minn. Agr. Exp. Sta. Id. 6th Ann. Rept. St. Ent. of the St. Exp. Sta. Univ. of Minn. pp. 168, 169. Fig. 148 after Riley.
1901. *Schizoneura americana,* Aldrich. Idaho Agric. Exp. Sta. Feby. Bul. 26, pp. 20-22. Records summer and fall (return) migration and describes true sexes. Suggests that alternate host plant may be grass.
1901. *Schizoneura rileyi,* Hunter. Aphid. of N. A., p. 84. Bibliography in part.
1902. *Schizoneura americana,* Weed, C. M. Bul. No. 90. N. H. Agr. Exp. Sta. p. 37. Brief account and photograph of curled leaf.
1902. *Schizoneura americana,* Cook, M. T. Galls and Insects Producing Them. Ohio Naturalist. Vol. II, No. 7, p. 265 and Fig. 12. Discussion of structure of gall.
1904. *Schizoneura americana,* Sanborn, C. E. Kansas Aphid. pp. 25-26, Plate VI, Fig. 37. Description of winged form and record of migration from elm.
1904. *Schizoneura lanigera,* Sanborn, C. E. Kansas Aphid. pp. 26-27. Fig. 36.
1904. *Schizoneura americana,* Cook, M. T. Galls and Insects Producing Them. The Ohio Naturalist, Vol. IV, No. 6.

1904. *Schizoneura lanigera,* Alwood, Wm. B. Circular in Relation to Some Injurious Insects and Plant Diseases. Special Bulletin (C. P. C. 45), Va. Exp. Sta. An excellent account of the insect and its work, with figures. A study of the true sexes in confinement is recorded followed by this significant statement: "We have not thus far been able to trace the migrant forms accurately, and watch the development of their young in normal situations. They behave in a very aberrant manner, and we are led to doubt the statements that their young are deposited in old colonies among the agamic forms. Definite search has not revealed them, nor have we been able to find the sexual egg in these old colonies. It is possible that there is here an unsettled problem which may have important bearing upon the distribution of the species."

1904. *Schizoneura americana,* Cooley, R. A. 10th Ann. Rept. Mont. Agr. Exp. Sta. pp. 43-45. Records this insect as a decidedly obnoxious pest in some parts of Montana on *Ulmus americana.*

1905. *Schizoneura americana,* Felt, E. P. N. Y. St. Mus. Memoir 8: pp. 172, 177-178. Description of leaf curl, and life history adapted from Riley.

1905. *Schizoneura rileyi,* Felt, E. P. N. Y. St. Mus. Memoir 8: pp. 172, 192. Brief description of work and remedies.

1907. *Schizoneura lanigera,* Smith, R. I. Bul. 23, Ga. State Board of Ent. An account after Alwood, with original photographs of work.

1908. *Schizoneura lanigera,* Gillette and Taylor. A Few Orchard Plant Lice. Bul. 133, Agr. Exp. Sta. of the Colorado Agr. College, pp. 5-23. Ecological and economic account with original figures.

1908. *Schizoneura lanigera,* Gillette, C. P. Journal of Economic Entomology, Vol. 1, pp. 306-308. Of the migrants and true sexes he writes: "We have had no trouble to get the alate females to deposit the true sexual forms in confinement. We have been utterly unable to keep these alate females upon the apple trees to deposit their young. They seem possessed of a controlling instinct to get away from the tree, so that the sexual forms have always been deposited upon the walls of the breeding cages. . . . . Since writing the above, I have succeeded in obtaining numerous examples of light orange yellow sexual females and the smaller dusky brown males, and a few yellow eggs upon leaves and bark of twigs that had been enclosed six weeks before in small cheese cloth sacks in the orchard."

1909. *Schizoneura rileyi,* Gillette, C. P. Journal Ec. Ent. Vol. 2, p. 357. Suggests that it may be same species as *Schizoneura ulmi* (*americana*). "Of common occurrence at Fort Collins and other places in Colorado.

1909. *Schizaneura lanigera,* Gillette, C. P. Journal Ec. Ent. Vol. 2, p. 356 and Fig. 15. "This is one of the most serious and generally distributed insect pests of apple orchards in Colorado.

1909. *Schizoneura ulmi* L. (*americana* Riley) Gillette, C. P. Journal Ec. Ent. Vol. 2, p. 356 and Fig. 16. "This louse is a real pest upon white elm nearly everywhere that this tree is grown in Colorado."

1910. Davis, J. J. A List of the Aphididae of Illinois with notes on some of the species. Jour. of Ec. Ent. Vol. 3, p. 412.
Schizoneura americana. "Not infrequently injuriously abundant."
Schizoneura crataegi. "A serious pest of the hawthorns used in ornamental plantings in Chicago."

1910. *Schizoneura americana,* Patch, Edith M. Gall Aphids of the Elm. Me. Agr. Exp. Sta. Bul. 181, pp. 223-235.

1910. *Schizoneura rileyi.* Patch, Edith M. Gall Aphids of the Elm. Me. Agr. Exp. Sta. Bul. No. 181, pp. 235-238.

1910. *Schizoneura americana.* Williams, T. A. The Aphididae of Nebraska, p. 16.

1910. *Schizoneura crataegi.* Williams, T. A. The Aphididae of Nebraska, p. 19.

1910. *Schizoneura lanigera.* Williams, T. A. The Aphididae of Nebraska, p. 20. Mere mention.

1910. *Schizoneura rileyi.* Williams, T. A. The Aphididae of Nebraska, pp. 20-21. "It causes a curling of the leaves similar to *S. americana,* but the galls can be readily distinguished as those of this species are much more tightly curled than those of *S. americana.* This latter species is often to be found on the same tree. They can be easily separated, as they differ in size, antennae, venation and other minor points."

1911. *Schizoneura lanigera.* Lohrenz, H. W. Jour. Ec. Ent. Vol. 4, pp. 162-170. Ecological and economic study.

1912a. *Schizoneura lanigera.* In Bul. No. 195 Me. Agr. Exp. Sta. Recorded on *Crataegus* and three species of mountain ash.

1912b. *Schizoneura lanigera* (*americana*). Patch, Edith M. Science, Vol. 36, p. 30. Progeny of spring migrants from elm reared on apple. . . .

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If the elm species of America and Europe are the same, this insect will revert to *Schizoneura ulmi* L. (*lanigera* Hausmann) and according to European Aphidists *ulmi* migrates to the roots of currant for the summer generations where it was described by Buckton as *Schizoneura fodiens.* Are there two species in Europe known as *ulmi,* one migrating to currant and the other to apple?

1909. *Schizoneura ulmi* L. (*S. fodiens* Buckton). Tullgren. Aphidologische Studien, pp. 163-169.

Fig. 448. Seedling apple photographed May 29, 1912, to show colony of woolly aphids which are the progeny of migrants from elm leaf curl received from the south May 12, 1912.

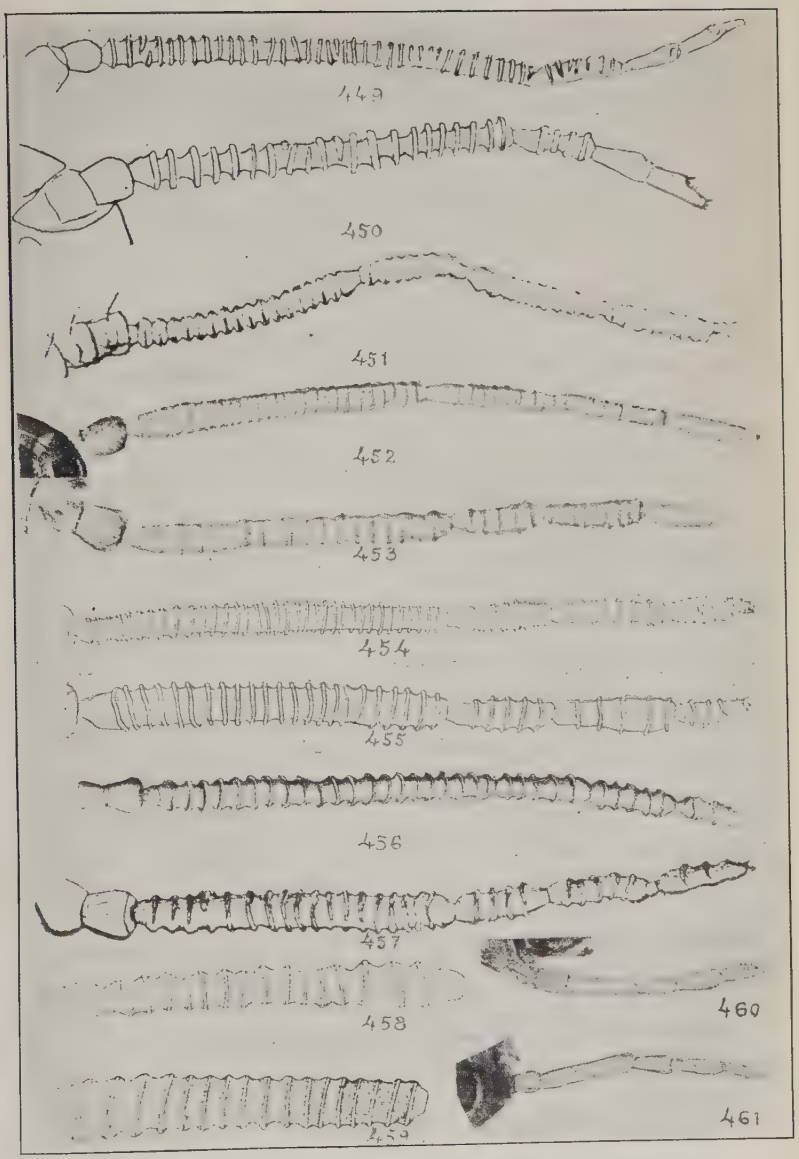

Fig. 449, *Schizoneura ulmi*. Spring migrant (Tullgren 1909). Fig. 450. *S. ulmi*. Fall migrant (Tullgren 1909). Fig. 451. *S. americana* (Riley 1879). Fig. 452. *S. americana* and Fig. 453 *S. rileyi* (Patch 1910). Fig. 454. *S. ulmi* and Fig. 455 *S. lanigera* (Gillette 1909). Fig. 456 *S. lanigera* (Alwood 1904). Fig. 457 *S. lanigera* (Marlatt 1897). Fig. 458 *S. americana* and Fig. 459 *S. lanigera* (Sanborn 1904). Fig. 460 *S. rileyi* and Fig. 461 *S. americana*, apterous viviparous forms. (Patch 1910).

Fig. 462. Terminal leaf curl or rosette of elm leaves. The habitat of the stem mother, the second generation, and the third generation previous to their migration.